GROUNDWATER STUDIES IN THE EDWARDS PLATEAU OF TEXAS

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CONTENTS

GROUNDWATER STUDIES IN THE EDWARDS PLATEAU OF TEXAS[1/]

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INTRODUCTION

The 20-million-acre Edwards Plateau in west-central Texas permits rapid recharge into its underlying groundwater, which is the principal source of water supply for numerous rural and urban communities. Its fractured limestone outcrops and surface openings, into which surface runoff can readily flow, have been presumed to be the primary mechanisms for recharge. Little information is available as a basis for evaluating this hypothesis. Neither is there sufficient information on rainfall-runoff relations.

There has been considerable speculation on the effects of fractures and surface openings in the bottoms of floodwater detention reservoirs on the disposition of stored runoff water. How much of this water drains through these openings, and how fast? Does this loss from storage represent recharge into groundwater, or is it a temporary loss from streamflow, reappearing at the surface at some point downstream from the reservoir?

The objectives of this investigation are (1) to provide information on rainfall-runoff relations, (2) to measure the disappearance of water from the floodwater detention reservoirs and the related fluctuations in nearby groundwater observation wells, and (3) to study sediment deposition in detention reservoirs, for a representative watershed in the Edwards Plateau.

This report consists of descriptions of Lowrey Draw watershed, its subwatersheds and reservoirs, and a study of the flow into the reservoirs, its subsequent disappearance, and the related groundwater fluctuations, during two runoff events.

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DESCRIPTION OF PROJECT

Geology of Study Area

The Edwards Plateau in west-central Texas (fig. 1), originally a smooth upland surface, was formed on nearly horizontal limestones of Lower Cretaceous age. Erosion of the plateau has resulted in a dendritic pattern of deep narrow valleys, with not more than 50 percent of the region remaining as nearly level upland. In central Texas the Lower Cretaceous rocks have been subdivided into the Trinity, Fredericksburg, and Washita groups (2). 3/ Within these groups, the Comanche Peak and the Edwards of the Fredericksburg, and the Georgetown of the Washita are formations that apparently correspond to the limestones of the Edwards Plateau, where, because of changes in lithologic character with increased distance westward, their individual identification is difficult or impossible. These three formations have been commonly grouped together as the "Edwards and associated limestones" in the Edwards Plateau region (1, 3, 5).

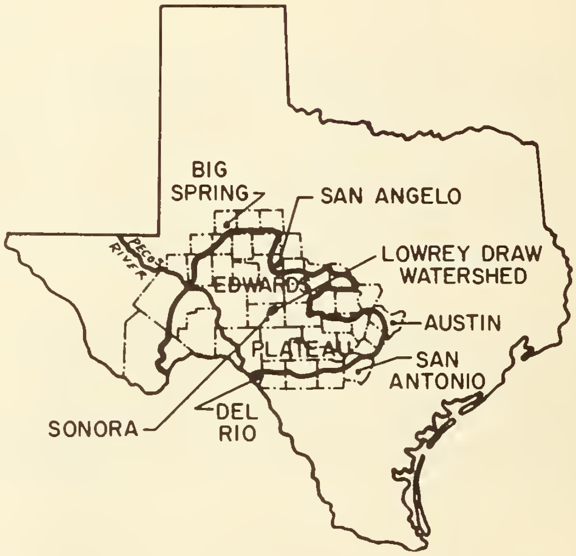

Figure 1.--Location of Edwards Plateau and Lowrey Draw watershed in Texas.

Although the common designation had been sufficient for most purposes, a water-bearing stratum had not been specifically identified, and a more detailed survey was needed for hydrologic research purposes. Therefore, H. R. Blank, consulting geologist for Agricultural Research Service, made a preliminary geologic survey of the Lowrey Draw watershed and surrounding area.4/ Well drillers' descriptive logs and geophysical exploration companies' radioactive neutron ray logs (6) were used to supplement information from surface geologic exposures. These data indicated that all the strata in the Lowrey Draw vicinity dip southwesterly at approximately 4.5 feet per mile.

In the Lowrey Draw watershed, the nearly level upland (plateau) areas are underlain by thin, hard limestone beds and thicker marly beds. The upper slopes of the valleys consist of alternating beds of hard limestone and marly limestone. Thick beds of hard limestone occur on the steep middle and lower slopes. The stream valleys are characterized by alluvial deposits. Flood

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3/ Underscored numbers in parentheses refer to Literature Cited, p. 12.

4/ Blank, H. R., Preliminary studies of the geology and groundwater of Lowrey Draw watershed in the Edwards Plateau. U. S. Agr. Res. Serv., Soil and Water Conserv. Res. Div. Res. Rpt. 364, 40 pp. 1963.

detention reservoir 9 (see fig. 3 on p. 5) lies in the strata of alternating beds of hard limestone and marly limestone; the major portion of the drainage is in the plateau layer. The other four reservoirs are located in alluvial channels underlain and bounded by thick limestone beds.

The thick, hard limestone beds are fractured and in places cavernous. The numerous caverns of various sizes in Lowrey Draw permit the downward movement of surface water at different rates and in different amounts. Many joints and fractures have become visible in reservoir bottoms after disappearance of storm inflow. Washing away of alluvial material by the drainage leaves the joints and fractures exposed.

Caverns the size of the one in figure 2 rapidly transmit water underground. Such caverns located upstream from the reservoir can intercept considerable surface runoff before reservoir inflow is observed.

Rocks exposed at Lowrey Draw possess little or no primary permeability, and it might be supposed that all the groundwater is contained in interconnected caverns and fractures. However, correlation of well records with samples from outcrops at springs in the surrounding region indicates the presence of a widespread water-bearing dolomitic zone in the subsurface. Shrinkage of the strata during dolomite formation created voids for water storage.

Figure 2.--Solution cavern in sediment pool near reservoir 10, Lowrey Draw watershed.

Selected Watersheds

The Lowrey Draw watershed near Sonora in Sutton County, Texas (fig. 3) was selected in 1960 as an area typical of the Edwards Plateau (fig. 1). This watershed has five floodwater detention reservoirs recently completed by the Soil Conservation Service under the provisions of P. L. 566. The five structures control the drainage from 70 percent of the 48-square-mile watershed.

Instrumentation

The reservoirs were equipped with water level recorders for continuous water stage measurements. Detailed topographic surveys were made in the flood pools of the reservoirs, and stage-storage relationships were developed. The observed rate of change of water level were applied to stage-storage relation to calculate reservoir inflow and depletion.

Table 1 shows the size of the drainage areas controlled by the five floodwater detention reservoirs and the maximum amount of stored water that might be available for groundwater recharge.

TABLE 1.--Size of drainage areas controlled by floodwater detention reservoirs and reservoir capacities

Reservoir No.	Drainage area	Reservoir capacity at emergency spillway level
	Acres	Acre-feet
9	1,774	590
10	5,392	1,865
11	10,787	5,195
12	2,801	1,110
13	686	330

Since the disposition of rainfall is an integral part of groundwater studies, a network of 14 rain gages (Nos. 1-A and 1 to 13, fig. 3) was established to provide rainfall data for Lowrey Draw watershed and the sub-watersheds. Existing water wells, not being pumped, (Nos. 1 to 12, fig. 3) and two wells (Nos. ARS-1 and ARS-2, fig. 3) drilled especially for the study were used to observe groundwater levels. Estimates of natural recharge could be made by correlating rainfall data with groundwater level changes.

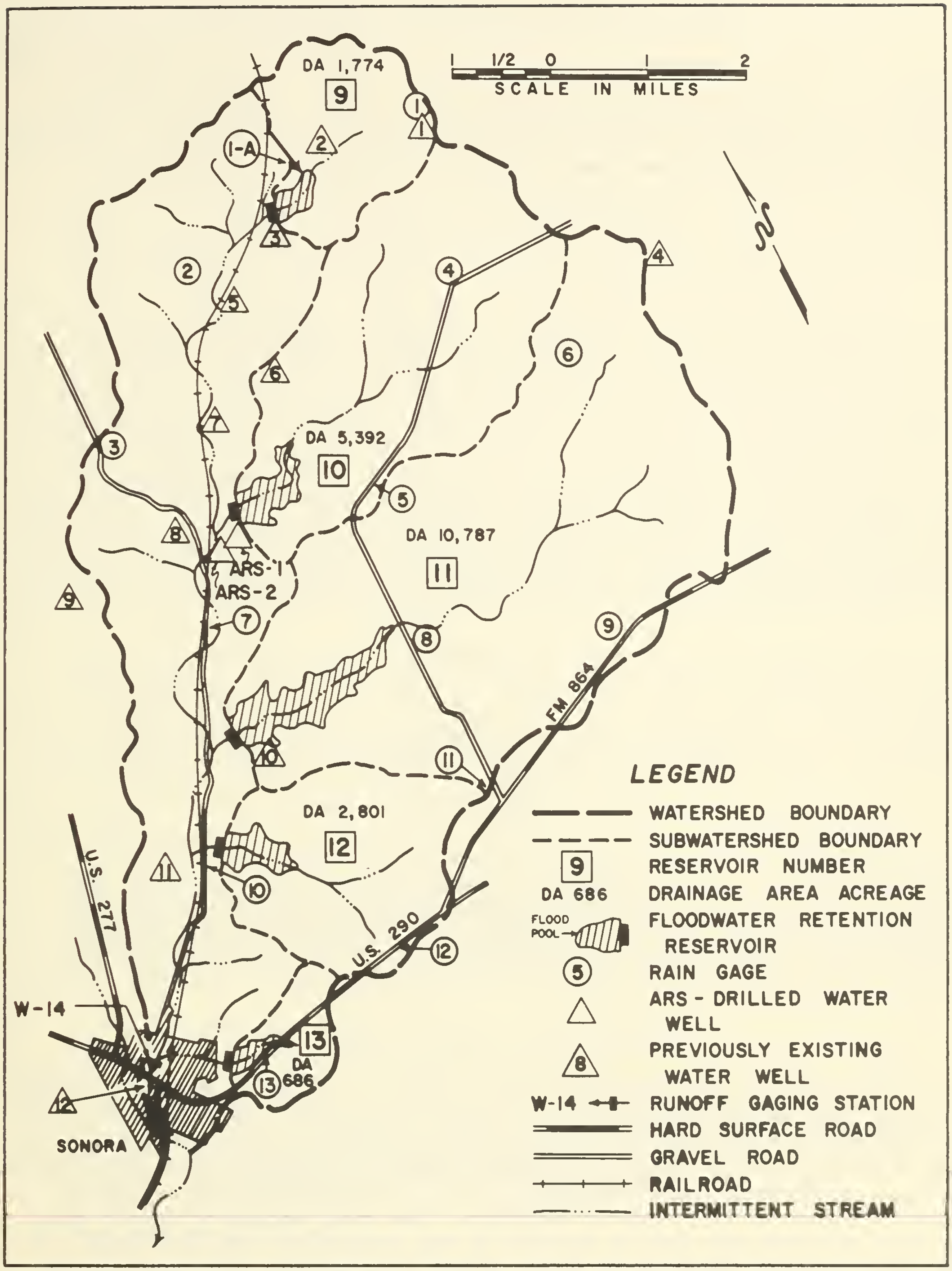

Figure 3.--Map of Lowrey Draw watershed Sutton County, Tex., showing floodwater detention reservoirs, rain gages, and groundwater wells.

Preliminary Observations and Preparations

A few storms in June 1961 produced small volumes of inflow into the reservoirs. Reservoir 9 held water for several weeks, whereas storage in reservoir 10 dissipated in a few hours and that at reservoirs 11, 12, and 13 remained only a few days. Observations following runoff periods in October of the same year indicated similar results. Groundwater observations at existing wells some distance from the reservoirs did not indicate rapid or appreciable rises, and therefore did not reflect rapid recharge from reservoir storage. These observations indicated the apparent need for wells located near the reservoirs in order to reflect small or rapid fluctuations.

Since reservoir 10 indicated the most rapid losses, the immediate area was selected for more intensive groundwater studies. Two wells were drilled in June 1962, down dip (southwest) from the reservoir. The first was located approximately 1,000 feet from the lowest point of the reservoir and the second an additional 1,300 feet away. These two well locations are shown in figure 3 as ARS-1 and ARS-2. In addition to providing groundwater elevations near the recharge area, these two wells provided geologic data for correlation with logs of the other wells in the watershed. Continuous water-stage recorders were installed in these wells to determine the time of groundwater level changes relative to reservoir inflow and the rate of groundwater movement. Water surface elevations in the previously existing wells were determined from periodic manual measurements.

One method of determining the length of time water has been in an aquifer is dating by evaluating tritium concentrations (4, 7, 8). Water samples were taken in late 1961 from a number of wells in the Lowrey Draw watershed and from springs in the surrounding area. The samples are currently (Sept. 1964) being processed to determine tritium concentrations.

RESULTS FROM TWO RUNOFF EVENTS

The first runoff-producing storm after the two wells were drilled near reservoir 10 occurred on Sept. 7, 1962, followed by another runoff-producing storm on Sept. 10. Although the volumes from both storms were small, they were the largest during 1962 for the Lowrey Draw watershed. Precipitation, groundwater data, and reservoir inflow and outflow for these runoff events are shown in table 2.

Flow of Runoff into Reservoir

The weighted precipitation data in table 2 do not adequately describe the intensity and distribution of the rainfall. The rainfall on Sept. 7 was relatively uniform over the watershed. Because the clay soil was dry, only a small amount of runoff occurred. A very irregularly distributed storm on Sept. 9 centered over the headwaters of the watershed and produced a weighted amount of 0.54 inch of rainfall. The small amount of runoff that may have occurred was lost in transit to the reservoir. The 0.17-inch (weighted average) rainfall on Sept. 10 was from another very irregularly distributed storm. The heaviest portion of the rainfall, 0.5 inch, was on an area of approximately 500 acres of stony soil and rock ledges near the

reservoir. The high intensity produced quick runoff. Since the runoff source was near the reservoir, and the previous rains had wet the soil, a large percentage of the surface flow reached the reservoir.

The two runoff-producing storms (Sept. 7, 10) caused negligible sediment deposition in the reservoir. The accumulation was insufficient to affect the flow through cracks and caverns in the bottom of the reservoir.

Reservoir Inflow Versus Rise in Wells

The groundwater data of table 2 show that the rise in the observation wells began before inflow was recorded in the reservoir. Since the wells lie downstream, this indicates that the approaching flow is intercepted by caverns and bottom openings before reaching the low point of the reservoir where the bubbler gage orifice is located. Apparently these openings are connected rather directly with the wells since the water level in well ARS-1 responded rapidly to the inflow, although the well is approximately 1,000 feet from the reservoir. On Sept. 7 all the initial small flow entered the caverns and inflow to the reservoir did not occur until the runoff rate exceeded the intake rates of the caverns. This initial cavern abstraction volume, however, was sufficient to affect the water table. On Sept. 10 the storm runoff rates increased more rapidly than for the previous storm and exceeded the intake rates of the caverns earlier in the runoff period. Therefore, reservoir inflow began nearer to the time the rise began at the well.

TABLE 2.--Time comparisons of groundwater movement and storm occurrence at reservoir 10, Lowrey Draw watershed, Sutton County, Tex., Sept. 1962

Date	Precipitation 1/			Reservoir 10				Rise in groundwater observation well			
				Inflow			Out-flow	ARS-1		ARS-2	
1962	Began	Ended	Amount	Began	Ended	Amount	Ended	Began	Ended	Began	Ended
	Time	Time	Inches	Time	Time	Acre-ft.	Time	Time	Time	Time	Time
Sept. 7	0200	0910	2.95	0422	0428	0.03	0438	0315	0330	1050	1330
Sept. 7	---	---	---	0448	0525	.08	0607	---	---	---	---
Sept. 9	1020	1110	.54	---	---	---	---	---	---	---	---
Sept. 10	1628	1830	.17	1635	2030	4.37	2103	1630	1730	2330	2/0130

1/ Precipitation amounts shown are Theissen weighted amounts for reservoir 10. Beginning times are earliest for any gage, and ending time is latest for any gage.

2/ Peak occurred on Sept. 11.

Groundwater Hydrographs

Groundwater observation well hydrographs are shown in figure 4 for three wells in the watershed. The well numbers correspond to those in figure 2. Recharge effects are clearly evident in well ARS-1 but not in wells number 3 and 12. Well ARS-2 showed a response similar to ARS-1, but the hydrograph is not shown on figure 4 because the compressed scale would make the hydrographs indistinguishable. The only reasonable explanation for the difference in performance of the wells is the nearness of reservoir 10 to wells ARS-1 and ARS-2. Wells 3 and 12 are apparently outside the sphere of influence of the reservoir. The difference cannot be attributed to differences in natural recharge by rainfall because rainfall for Sept. 7 was relatively uniform over Lowrey Draw watershed. Therefore, all wells should have had equal opportunity for natural recharge.

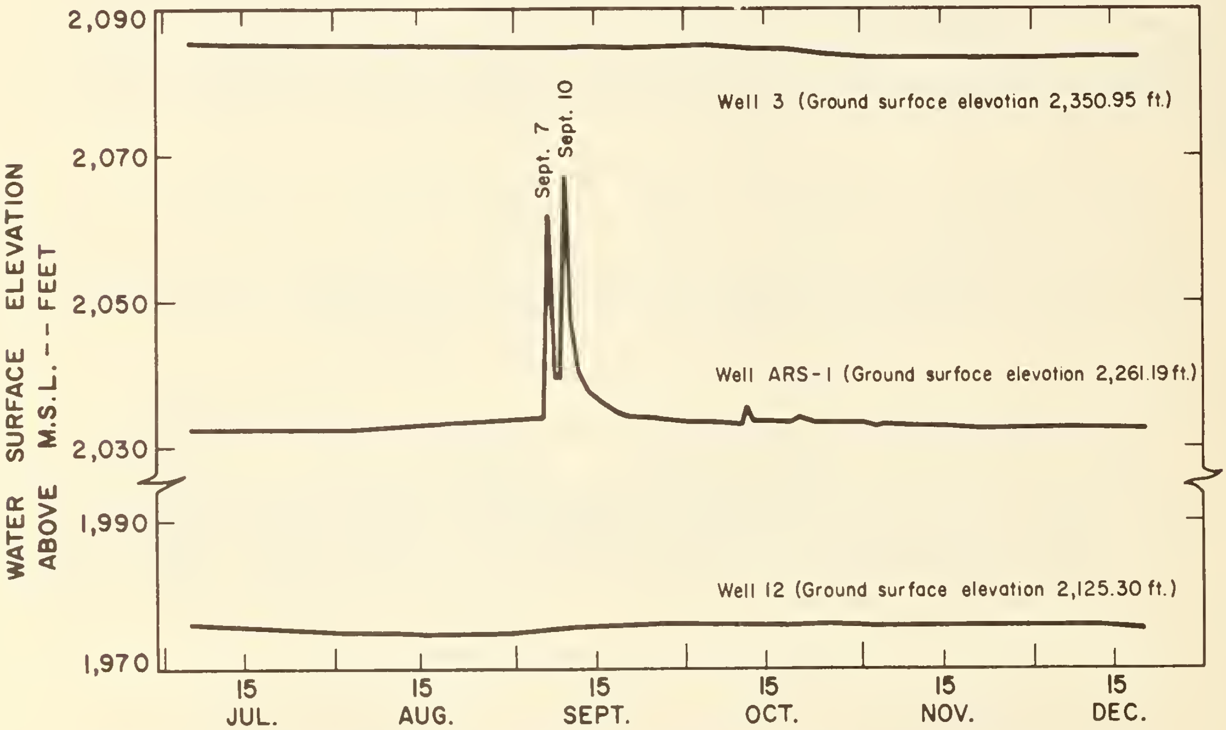

Figure 4. -- Groundwater observation well hydrographs for wells 3, 12, and ARS-1, Lowrey Draw watershed, Sutton County, Tex., 1962.

Detailed hydrographs for wells ARS-1 and ARS-2 are shown for Sept. 7 to 12 in figure 5. In general, the shapes of the two hydrographs in figure 5 are very similar except that a secondary rise at well ARS-2 on Sept. 7 did not occur at well ARS-1. The time lag between corresponding peaks at the two wells was different on Sept. 7 and Sept. 10. The relative time lags in hydrograph rises help substantiate the previous theorized condition of initial inflow entering caverns upstream from the reservoir. The maximum rise was greater than anticipated for the small runoff volumes. The rapid rises indicate that the caverns in the reservoir bottom have large openings which are directly connected to the aquifer. Percolation through the geologic mantle would have been much slower and caused the rises to be much less pronounced.

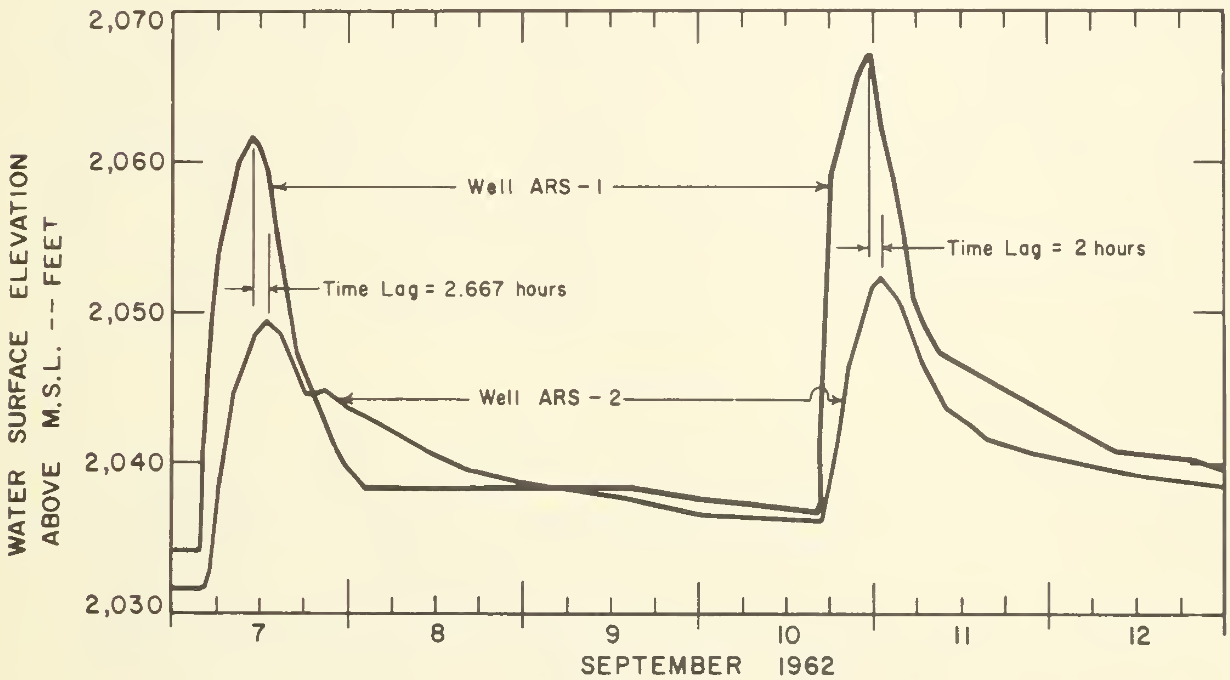

Figure 5. -- Groundwater well hydrographs for wells ARS-1 and ARS-2, Lowrey Draw watershed, Sutton County, Tex., 1962.

Groundwater Surface Cross Section

Groundwater elevations from measurements on Sept. 10 are shown in figure 6 for a number of observation wells. Wells were selected along either side of a line extending from a point near reservoir 9 (near the upper Lowrey Draw watershed divide) in a southwest direction toward the city of Sonora. This line approximates the direction of geologic dip. The well locations were projected to the line and the individual water elevations were joined by straight lines. Data for well numbers 1, 4, and 9 were not plotted since the wells are a considerable distance from the assumed line and areal irregularities of the water table would be misleading. Measurements were not made at wells 5 and 7 on Sept. 10. Peak elevations of wells ARS-1 and ARS-2 were also plotted on figure 6. Since the groundwater elevations did not change at wells 2, 3, 6, 8, 10, 11, and 12 on Sept. 10, the peak elevations of the two ARS wells indicate the local effect of the reservoir on groundwater recharge for that date. The groundwater recharge mound was assumed to be cone shaped (6), with the apex of the cone directly below the reservoir. With the peak elevations at wells ARS-1 and ARS-2 as two points on the slope of the cone, a straight line was projected through the two elevations and extended to the location of the reservoir. Assuming the same groundwater surface slope on the up-dip side of the reservoir, the recharge cone was completed and appears as a triangle on the two dimensional cross section of figure 6. An extension of each side of the triangle was drawn to intersect the groundwater cross section from other wells along the line. The figure indicates that the effect of the mound extended for an up-dip and down-dip distance of 0.4 and 0.8 mile from the reservoir, respectively. Well 8 is approximately 0.5 mile from the reservoir at a right angle to the dip. This lateral distance is probably slightly outside the cone of influence since well elevation readings did not indicate a rise. A small rise may have occurred, but it was not detected by the periodic elevation measurements.

CONCLUSIONS

Groundwater studies in the Lowrey Draw watershed (Sutton County, Tex.) indicate that large volumes of water can be rapidly transmitted underground by caverns and solution channels in the bottoms of stream channels and flood detention reservoirs. Groundwater observation well data near a floodwater detention reservoir indicate that water transmitted underground goes directly to groundwater. Water table fluctuations begin simultaneously with reservoir storage depletion. Fluctuations indicate that caverns upstream from the reservoir transmit small amounts of streamflow to the aquifer before inflow to the reservoir is observed. Groundwater recharge from rainfall passing through the soil and rock mantle is slow and may continue for a period of time after rainfall, whereas recharge from reservoir storage is of short duration and a definite groundwater mound can be detected in observation wells.

The runoff volumes during the September storms were of such small magnitude that sediment deposition in the reservoirs was not significant. The slight accumulation did not justify a resurvey and data are not available.

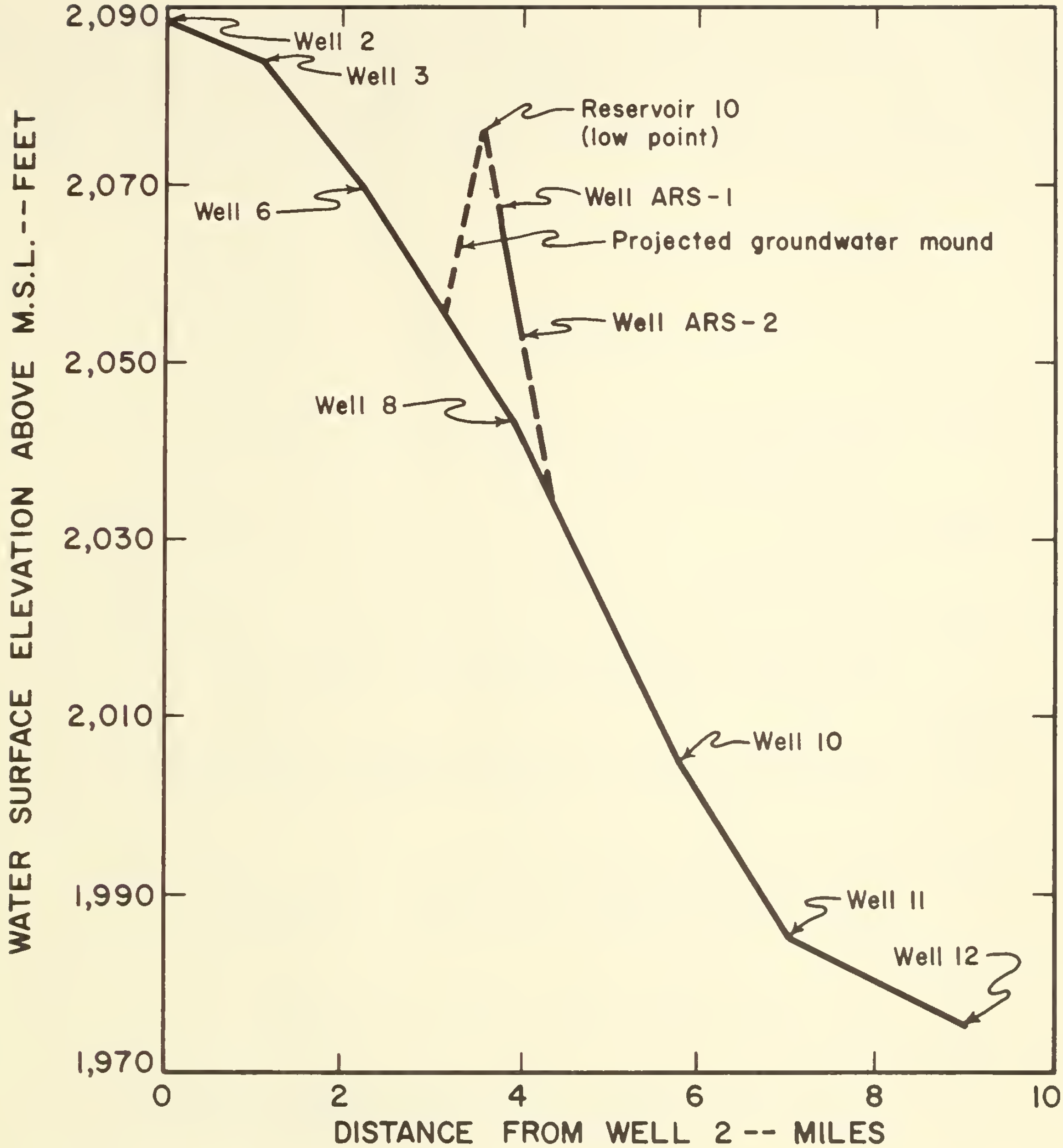

Figure 6.-- Cross section of groundwater surface on Sept. 10, 1962, for well locations projected to a line extending from near reservoir 9 to Sonora in Lowrey Draw watershed, Sutton County, Tex.

Data are insufficient to be conclusive or to permit development of any relations at this time. However, the data collection program initiated will provide estimates of groundwater recharge possibilities in connection with flood detention structures. The research data will also help groundwater hydrologists determine the feasibility of establishing reservoirs primarily for groundwater recharge.

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